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APPLICATION

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TITLE:           TIME SHIFTING BY SIMULTANEOUSLY  
                  RECORDING AND PLAYING A DATA STREAM

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TIME SHIFTING BY SIMULTANEOUSLY RECORDING  
AND PLAYING A DATA STREAM

Cross-Reference to Related Application

This is a continuation-in-part of U.S. patent application, serial no. 08/996535, filed December 23, 1997.

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Background

This present invention relates to the recording and playing back of a video stream. A video stream includes any combination of audio and/or video data streams.

10       Video streams have typically been recorded on analog media such as a video cassette. A video cassette recorder (VCR) is used to record the video stream on the video cassette. The video stream may come via a broadcast signal, via cable, via satellite signal, or from another  
15       video playback device. Once the video stream has been recorded, the VCR is used to rewind the recording medium and play what was recorded. However, due to the nature of the analog medium, once the VCR has started recording, it is not possible to play back the portion of the video  
20       stream that has already been recorded until the recording session is terminated.

      For example, imagine that a person sets up a VCR for recording a one hour show because he knows that he will miss the first 15 minutes of the show. When he arrives  
25       home 15 minutes into the show, he will have to wait for the entire show to be recorded before he can start watching the program from the beginning. A way of being able to view

the show from the beginning without having to wait for the recording session to terminate is desirable.

### Summary

5        A method of enabling a video stream to be stored and displayed at the same time including allowing portions of the video stream to be alternately written to and read from a storage device. The next portion to be written to the storage device is stored in a temporary buffer while  
10       another portion is being read from said storage device.

### Description of the Drawings

15       Figure 1 shows a block diagram of a video record and playback system in accordance with one embodiment of the invention;

      Figure 2 shows a flow chart of the method of providing a time-shifted video stream;

      Figure 3 shows one embodiment of performing block 206 of Figure 2;

20       Figure 4 shows one embodiment of an apparatus for storing the video stream on a hard disk;

      Figure 5 shows an exemplary method of using the storage unit as a temporary buffer.

25       Figure 6 shows a flowchart of the playback of a video stream catching up to the incoming video stream;

      Figure 7 shows another embodiment, in which the user is able to suspend the display of the incoming video stream;

30       Figure 8 shows an example of a display screen with several image frames taken at different times;

Figure 9 is a flow chart showing one system for recording and playing back a video stream;

Figure 10 is a block diagram of a computer system useful in implementing one embodiment of the present invention;

Figure 11 is an exemplary TV display for implementing an embodiment of the present invention;

Figure 12 is a flow chart showing the operation of another embodiment of the present invention;

Figure 12A is a continuation of the flow chart of Figure 12.

Figure 13 is a top plan view of a remote control useful in one embodiment of the present invention;

Figure 14 is a block diagram showing how data is transferred to, and from a memory device;

Figure 15 is a flow chart showing the flow of input video information into a storage device;

Figure 16 is a flow chart showing the flow of data from the storage device; and

Figure 17 shows a display with an electronic program guide.

#### Detailed Description

Figure 1 shows a block diagram of a video record and playback system 100 in accordance with one embodiment of the invention. A video stream is received at the video input 102. The video stream may be provided by a camera, a television signal, broadcast, cable, or satellite signals, or another video playback device. In one embodiment, the video input 102 performs an analog-to-digital conversion on

an analog video stream to form a digital video bit stream. In a different embodiment, the video is already in digital form. The video record and playback system 100 may be part of a computer system such that the video input 102 is a  
5 video capture card in the computer system.

The digital video stream from the video input 102 is optionally compressed at compression unit 104. In one embodiment, the video is already compressed, such as would be the case with an Moving Picture Experts Group 2 (MPEG 2)  
10 specification (available from the International Standards Organization Standard ISO1172) compliant video signal, and no further compression is needed. The video stream is then stored in the storage unit 108. A buffer unit 106 may be used as temporary storage for providing larger sequential  
15 blocks of video data to the storage unit 108. In one embodiment, the storage unit 108 is a random access memory that allows relatively quick access to any portion of the stored video stream. A hard disk is an example of a random access memory.

The video stream is played back by reading the video stream from the storage unit 108. If the video stream was compressed in compression unit 104, then a decompression unit 110 decompresses the retrieved video stream. The video stream is provided from a video output port 120, to a  
20 monitor or other display device to provide sound and/or  
25 video to a user.

A removable storage unit 122 may also be included in video record and playback system 100, Examples of removable storage units are a writeable compact disk read  
30 only memory (CD-ROM), writeable digital video disk (DVD), a

flash memory, or another hard disk. The removable storage unit 122 allows a user to transfer a recording of a video stream stored in storage unit 108 to the removable storage unit 122 and then to transfer the unit 122 to another  
5 system at a different location.

In one embodiment, a processor 130 controls the operations of the video record and playback system 100. The compression unit 104 and decompression unit 110 may be implemented in hardware, or the compression and  
10 decompression functions of units 104 and 110 may be performed by the processor 130. Processor 130 receives instructions from firmware/memory 140, using technology that is well known.

Figure 2 shows a flow chart of the method of providing  
15 a time-shifted video stream. The flow chart begins at block 200, and continues at block 202 where the video stream is received. The recording of the video stream begins at block 204. At block 206, playback of the recorded video stream is performed by retrieving a portion  
20 of the video stream from the random access storage unit while the recording of the incoming video stream continues. The retrieved portion of the video stream may be time-shifted from the incoming video stream by a time delay. At block 208, the portion of the video stream retrieved from  
25 the random access storage unit is retrieved for display by a television or other display device.

In this way, the record and playback functions are decoupled from one another. The user may now begin watching a recorded TV show from the beginning, i.e., prior  
30 to the show being completely recorded.

Figure 3 shows one method for retrieving a portion of the video stream from the random access storage unit while continuing to record the incoming video stream. In the disclosed embodiment, the simultaneous recording and playback of the video stream is performed by multiplexing or alternately storing the video stream to the random access storage unit and reading of the video stream from the random access storage unit. The multiplexed or alternated stores and reads may occur quickly enough that the user does not notice an appreciable delay in the playback of the video stream, and the incoming video stream is not lost, i.e., all of the video stream is recorded. Thus, the record and playback are simultaneous from the user's point of view.

In one embodiment, the random access storage unit is a hard disk. The retrieval of the time-shifted video signal from the hard disk is performed at a first physical location (or sector) of the hard disk, and the storing to the hard disk of the incoming video stream is performed at a different physical location (or sector) on the hard disk. Because it takes more time to jump back and forth between different sectors of the hard disk than to read and write to sequential locations in the same sector, data may be buffered to minimize the number of accesses to and from the hard disk using buffer 106. This increases the amount of data transferred per access.

Additionally, because of time constraints for reading and writing to the hard disk, data may be compressed and decompressed to speed transfers to and from the hard disk.

In block 302, the video stream is stored in a random access storage unit. The video stream is optionally compressed and/or buffered prior to storage. In block 304, the video stream is retrieved from the random access storage unit. Buffering and/or decompression may be performed before providing the retrieved video stream to the video output port 120.

The next portion of the video stream is stored (block 306) as described in block 302. At block 308, the next portion of the video stream is retrieved as described in block 304. This process is repeated until either the recording or playback cycle is terminated.

Figure 4 shows one embodiment of an apparatus for storing the video stream in the storage unit 108. In this embodiment, the video stream is stored as separate files 001 and 009 on a hard disk, for example. The processor 130 keeps track of the file and offset into the file of the data being played back, as well as the file and offset into the file of the data being recorded. If the random access storage unit is fast enough, more than one video stream can be recorded and played back at the same time.

Due to the nature of the random access storage unit being capable of easily recording over itself, the random access storage unit may act as a temporary buffer for recording the latest portion, or X number of minutes, of an incoming video stream, where X is set up based upon the size of the storage unit. In one embodiment, X could be set up to be the entire storage unit. As newer portions of the video stream are received, they overwrite the older portions of the video stream saved in the random access



storage unit. In this manner, the temporary buffering of the video stream acts as a circular buffer. In one embodiment, the processor 130 maintains pointers to the beginning and ending points of the temporary buffer. The processor 130 reassigns the pointers as newer portions of the video stream are received and/or older portions of the video stream are overwritten.

Figure 5 shows a flow chart 500 of one method for using the storage unit as a temporary buffer. At block 502, the video stream is received at an input. Recording of the video stream to the storage unit begins at block 504. At block 506, older portions of the video stream are deleted as newer portions of the video stream are stored to the storage unit.

A user may initiate a playback cycle following block 506. For example, this may occur when the user wishes to re-view a video clip that he just saw. In one embodiment, the user stops recording to the temporary buffer and plays back the last portion of the temporary buffer.

However, it may be more desirable to the user to be able to continue recording as shown at block 508. A record and playback cycle (as described with respect to Figure 2) is started, in which the incoming video stream is recorded while the user re-views the last portion of the temporary buffer. In this manner, after re-viewing the desired video clip, the user can resume sequentially watching the video stream from the point of the video clip.

At block 510, after the record and playback cycle is completed, all or part of the temporary buffer may be saved. Since the temporary buffer stores the latest X

minutes of the video stream prior to the record and playback cycle, all or part of the temporary buffer may be allocated to the portion of the video stream saved during the record and playback cycle. Other portions of the video stream may then be deleted from the storage unit, or they  
5 may be marked as overwriteable and used as a new temporary buffer.

Figure 6 illustrates a method for playing back a video stream to allow the playback to catch up to the incoming video stream. Usually, during simultaneous playback and recording of the same video stream, the playback of the video stream is time-shifted from the incoming video stream by a time delay. However, if the playback is performed at an overall rate faster than the rate at which the incoming video stream is received, then the playback will catch up to the incoming video stream.  
10  
15

For example, playback of the video stream may have an overall rate faster than the rate of the incoming video stream if the playback is fast forwarded, or if segments of the playback are skipped altogether. When the time delay of the time-shifted video stream being played back falls below a certain threshold, the video and playback system  
20 will cease providing the time-shifted video stream from the storage unit. Instead, the incoming video stream will be provided to the video output port 120 directly. In one embodiment, a bypass 142, as shown in Figure 1, allows the incoming video stream to be provided to the video output port 120 directly.  
25

When this happens, the user has caught up to the  
30 "live" broadcast, i.e., the incoming video stream. The

user may terminate the recording cycle, if he wishes.  
Alternatively, the user can put the video record and  
playback system 100 back into the temporary buffering mode  
in which only the latest portion of the video stream is  
5 stored.

Figure 7 shows an embodiment in which the user is able  
to suspend the display of the incoming video stream. This  
can be used for example, when the user is interrupted, and  
wishes to continue viewing the video stream after the  
10 interruption. When interrupted, the user signals to the  
video stream and playback system 100 to suspend the display  
of incoming video stream. This can be done via a remote  
control, for example. At block 702, the video output is  
suspended. In one embodiment, the video output continues  
15 to provide a still image of the image present at the  
instance when the suspend was encountered.

At block 704 the incoming video stream is recorded but  
is not displayed to the monitor. Instead the playback is  
paused at the point at which the user indicated that the  
incoming video stream be suspended. When the user is ready  
20 to view the video stream again, he can signal the video  
record and playback system 100 to un-suspend the video  
stream so that it plays back from the point at which the  
video stream was suspended, as shown in block 706.

25 The user may then view the video stream time shifted  
by the amount of time that he suspended the incoming video  
stream, or he may fast forward (or rewind) through the  
time-shifted video stream. When playback of the time-  
shifted video stream catches up to the point at which the  
30 incoming video stream is being recorded, the record and

5 playback system 100 may display the incoming video stream directly from incoming video stream without retrieving the video stream from the storage unit, as described with respect to Figure 6. The recording of the video stream may then be terminated by the user, if desired.

10 Employing a random access storage unit for storage of the video stream facilitates jumping to various points within the video stream. One way of jumping is by retrieving different time slices of the video stream. For example, an image frame from the video stream can be retrieved from the storage unit at 1 minute intervals from a current position of the video stream. In one embodiment, an image frame at the current playback position + 1 minute, current playback position + 2 minutes, and so forth are  
15 retrieved and displayed on the TV screen.

20 Figure 8 shows an example of a display screen 800 which displays several image frames taken from the video stream at different times. In Figure 8, the current playback position is designated as X. In one embodiment, the time interval, T, is user programmable. The intervals may be multiples of the time interval, as shown. A small interval may be used if the user wishes to skip a commercial, which usually lasts only a few minutes. Longer intervals such as a half hour may be useful for determining  
25 which movies are recorded on a storage unit.

After the image frames are displayed, the user is able to select one of the frames as a new starting point to which to begin an operation, such as a playback or record operation. By using such a story boarding method, it is

easy for a user to quickly jump to a desired location within the video stream.

In one embodiment, the record and playback system 100 is able to detect a black screen or fade out, such as those  
5 which accompany the beginning or end of a commercial. This is useful in editing a video stream.

Having the video stream stored on a random access storage unit such as a hard disk allows for easy editing of the video stream. Individual frames of the video stream  
10 may be deleted or replaced. For example, a commercial may be replaced by a fade-to-black sequence.

Once the video stream on the storage unit has been edited, it can be stored to a more permanent medium such as a writeable CD-ROM, flash memory, or another hard disk via  
15 the removable storage unit 122.

Referring now to the embodiment shown in Figure 9, a flow 900 for digitally recording a video stream begins by capturing the video stream as indicated in block 902. If the stream is an analog stream, it may be digitized in an analog-to-digital conversion process as indicated at block 904. Next the digital stream may be encoded and compressed, for example using the MPEG2 compression scheme, as indicated in block 906. The stream is alternately read, as indicated at block 910, and stored, as indicated in  
20 block 908, in a conventional storage device such as a hard disk drive, a digital video disk or a flash memory. Data that is read from the storage device is decoded and decompressed using conventional technology, as indicated in  
25 block 912, for display as indicated in block 914.

A computer system 1000 in accordance with one embodiment of the present invention, shown in Figure 10, includes a processor 1002. In one embodiment, the processor may be coupled to an accelerated graphics port (AGP) chipset 1004 for implementing an accelerated graphics port embodiment. The chipset 1004 communicates with the AGP port 1005 and the graphics accelerator 1006. The television 1010 may be coupled to the video output of the graphics accelerator 1006. The chipset 1004 accommodates the system memory 1008. The chipset 1004 is also coupled to a bus 1012 which may be, for example, a peripheral component interconnect (PCI) bus. The bus 1012 connects to TV tuner/capture card 1014 which is coupled to an antenna 1015 or other video input, such as a cable input, a satellite receiver/antenna or the like. The TV tuner and capture card 1014 selects of a desired television channel and also performs the video capture function (block 902, Figure 9). One exemplary video capture card is the ISVR-III video capture card available from Intel Corporation.

The bus 1012 is also coupled to a bridge 1016 which couples a hard disk drive 1018. The software 1020, 1022, 1024, 1026, 1028, and 1030 may be stored on the hard disk 1018. The bridge 1016 is also coupled to another bus 1032. The bus 1032 may be coupled to a serial input/output (SIO) device 1034. The device 1034 is in turn coupled to conventional components such as a mouse 1036, a keyboard 1038, and an infrared interface 1040. Also connected to the bus 1032 is a basic input/output system (BIOS) 1042.

An exemplary display 1100, shown in Figure 11, for the television 1010 may display a conventional television

picture or program 1101 and, in addition, may have superimposed over the screen, in a discrete fashion, a mouse selectable series of icons, such as the icons 1102 through 1114. When the mouse cursor 1116 selects the appropriate one of the icons, a corresponding feature may be implemented. Among the features that may be implemented in this fashion include a pause or stop function 1102, a start record function 1104, a fast forward function 1106, a rewind function 1108, and a 10 second reply function 1110 which winds back 10 seconds and replays, and a catchup function 1112 that begins playing back recorded content at a faster than normal rate until the display catches up with a live broadcast and an electronic program guide 1114.

Referring next to Figure 12, a program 1020 called display is used to control various features implemented by the computer 1000. Initially a check is made at diamond 1200 to determine if an electronic programming guide (EPG) is implemented. An electronic programming guide is an electronic depiction of the various programs that are available at different times. The electronic programming guide can be provided on a disk, over a modem, by an Internet connection and using an interactive broadcasting transmission such as Intericast<sup>®</sup> 2.0 interactive broadcasting software available from Intel Corporation.

If a particular television program is selected (even if the program is only selected for viewing) on the EPG, an identifier for that particular program is stored, as indicated at block 1202, and automatic recording of the program begins (block 1204). In this way the stored version of the program is available to implement the

various features described herein even if the storage function was not particularly requested. Because the information is stored in an overwriting fashion, no harm is done by recording the information even if the information turns out not to be useful.

Referring to Figure 17, an electronic program guide user interface 1700 may be deployed on the television 1010. When the user mouse clicks a box image 1702, representing a given television program, using the cursor 1116, that program is automatically recorded.

Continuing in Figure 12, an inquiry (diamond 1206) checks whether the user has selected the zoom feature for playback. If the user presses a zoom button during playback, a zoom feature is implemented. In one embodiment, five predefined quadrants in the television display may be defined including four quadrants located peripherally around a central quadrant. When the user selects the zoom feature the user indicates the appropriate quadrant for the zoom (block 1208). The selected quadrant is scaled (block 1210) to produce a larger (zoom) picture.

Referring to block 1208, the pointer focus is identified to determine which quadrant will be zoomed. That quadrant is then scaled as indicated at block 1210. Because the television program is continually being stored, the scaling can be implemented without any loss of continuity of the television picture. After the user has completed looking at the zoomed depiction, the user can return to the program at the point where he or she departed to view the zoomed depiction. Thereafter the displayed depiction viewed by the user may be time delayed from the



actually broadcast program. However the user is able to view the program in its entirety even if slightly time delayed.

5       Next a query is made at diamond 1212 to determine whether a pause function has been selected. If so, the playback is stopped as indicated at block 1214 but recording continues unabated as shown in block 1216.

10       The next check determines whether the play feature has been selected (block 1218). If so the recorded content is played thereby terminating the live display. However, while the recorded content is displayed, recording continues as indicated in block 1222 so that the recorded content may be eventually displayed without disrupting the continuity of the program.

15       A query finds out if the fast forward feature has been implemented as indicated in diamond 1224. If so, a fast playback is implemented as shown in block 1226. Once the playback equals the current broadcast or program content (diamond 1228), the flow returns to display current  
20       broadcast or program content. The fast forward may progress at 300 to 400% of normal playback speed.

25       Moving on to Figure 12A, at diamond 1230 a check is done to see if the 10 second replay feature has been activated. If so, the storage device is operated to find the content which was recorded 10 seconds ago (block 1232). The recorded content is then played (block 1234) from the 10 second period back to present. This would correspond to the replay feature implemented with broadcast television sporting events. After the "rewind" and playback of 10  
30       seconds has been completed, the system is automatically

transferred to automatic play and the recorded content that was displayed during the replay is displayed so the user does not lose any continuity in the show. Of course, the user can set the amount of time for the replay to be something other than 10 seconds.

A catchup feature is checked (diamond 1230) and, if this feature has been selected, an accelerated playback option is implemented (as indicated in block 1238). In the accelerated playback, the playback may be slightly increased in speed, for example from 105 to 115% of actual speed, so the user can easily follow the program but can make up for lost time to get back into the program as broadcast. Once the recorded program catches up to the real-time program as indicated in diamond 1240, the catchup feature is completed and the user returns to real-time display.

Control over the record and playback functions may be implemented through a normal mouse function, for example by clicking on icons as indicated in Figure 11. In addition, the record and playback features may be controlled remotely even when the user is not proximate to a keyboard or mouse. This may be done using a conventional remote control operator which may, for example, utilize infrared radiation.

As indicated in the depiction of an exemplary computer system 1000 (Figure 10), an infrared adapter 1040 may be provided, for example in compliance with the standards and specifications (such as Infrared Data Association Serial Infrared Link Access Protocol Version 1.0, June 23, 1994) of the Infrared Data Association (which can be found at

{www.irda.org}). The remote control 1300, as shown in Figure 3, may be utilized as a separate stand alone remote control or its features may be incorporated into a global remote control. The illustrated control 1300 is a stand alone control for controlling the record and broadcast features. It includes an infrared transmission port 1302 and a plurality of buttons to control the various features. For example a zoom function 1312 may be implemented as a four-way rocker switch. A zoom is implemented for the top quadrant of a display by pressing the upper edge of the button. If the button is pressed in the middle, the center quadrant is chosen for zoom. Likewise any of the remaining three edges of the zoom button can be operated to select a desired quadrant for zoom features.

A button 1306 is provided to implement the replay function, a button 1308 may implement the pause feature, and an enter button 1310 may be provided to allow entry of various information including a particular television program station. An on/off button 1314 may also be provided. Fast forward may be implemented by button 1316, an electronic program guide may be called by pressing button 1304. The catch up feature may be called by the button 1318, and a 10 second reply may be implemented by the button 1320. A conventional numeric keyboard 1322 may be provided to input additional information including selected television channels.

Techniques for storing the video stream onto the storage device 1410 and for reading the information out of the storage device are summarized in Table 1 below and illustrated in Figures 14, 15, and 16. In Figure 14, a

schematic depiction of the storage system 1400 includes a digital storage device such as a hard disk drive 1410. The digitized video 1402 is initially stored in a buffer which is designated as being currently on the top of the memory stack. The transfer of information between the buffers and the storage device 1410 may be done in discrete time

Buffers	Time Steps								
	1	2	3	4	5	6	7	8	9
Input	1404	1408	1406	1404	1408	1406	1404	1408	1406
Storage Read	X	X	X	1412 1414	X	1414 1416	X	1412 1416	X
Write	X	X	1404 1408	X	1404 1406	X	1406 1408	X	1404 1408
Output	X	X	X	X	1414	1412	1416	1414	1412

Table 1 (X = no action)

periods referred to herein as time steps. In a first time step, shown in Figure 15, the digitized video 1402 (Figure 14) is stored in memory buffer 1404 because that buffer is currently at the top of the memory stack, as indicated in block 1502 in Figure 15.

As the buffer 1404 fills up, the buffer 1408 moves to the top of the stack (as indicated by the dashed arrow) and incoming video is stored in buffer 1408. As indicated in block 1504 in Figure 15 in time step 2, the buffer 1408 replaces the buffer 1404 as the designated top of the stack buffer. The next input video is then stored in the new buffer (1408) as indicated in block 1506.

In time step 3 the buffer 1408 has filled up and the contents of buffers 1404 and 1408 are written to the storage device 1410 in a single write operation. During

the same time step, buffer 1406 moves to the top of the stack and becomes the storage buffer for incoming video. This is illustrated in blocks 1508, 1510 and 1512 in Figure 15.

5        In time step 4, the buffer 1404 moves back to the top of the stack to store incoming video since its previous content has already been saved in the storage device 1410. This is indicated in block 1514 of Figure 15, and in Figure 16 in block 1602. The storing of incoming information, as  
10        illustrated in Figure 15 then cycles back to the top of the flow in Figure 15 and continues in the same fashion thereafter.

      The content from the storage device 1412 is then read into buffers 1412 and 1414.

15        In time step 5, the buffer 1408 moves to the top of the stack to store incoming video, and buffer 1414 moves to the top of the output stack and transfers data to the video output 1418. The contents of the buffers 1404 and 1406 are then written to the storage device 1410.

20        The time steps 1 to 5 illustrate a complete cycle from input to output. The remaining sequence of steps repeat starting at step 5 for the input of data and time steps 6 through 9 repeat for the output of data.

      Referring now solely to Figures 14 and 16, in time  
25        step 6, information stored in the storage device is read to the sixth and fourth buffers (i.e., buffers 1414 and 1416) as indicated in block 1606. The contents of the fifth buffer (1412) are sent to the output 1418.

In time step 7, the contents of the sixth buffer (which is buffer 1416) are sent to the output 1418. No other output operations occur.

5 In time step 8, the contents from the storage device 1410 are read into the fifth and sixth buffers (buffers 1412 and 1416) as indicated in block 1612. Also the contents of the fourth buffer (buffer 1414) are passed to the output 1418 as indicated in block 1614.

10 Finally, during time step 9 the contents of the fourth buffer (buffer 1412) are passed to the output 1418, completing the cycle.

Using these algorithms, the storage device is provided with enough time, through the operation of the buffers, to write the incoming video while supplying enough data  
15 simultaneously to the output display. Since the memory is used to make sure no content is dropped at the input end and the display is never starved at the output end, continuous, even display can be provided without losing information. In addition reading and writing larger chunks  
20 of data at one time minimizes the amount of storage device head movement, thereby allowing the storage device to keep up with the read and write requests.

The minimum size of the individual buffers 1404 to 1408 and 1412 to 1416 ("B") is dependent on a number of  
25 factors including the input/output data rate "D", for example in megabytes per second, the effective bandwidth of the storage device when reading or writing "S", for example in megabytes per second, and the average seek time for the storage device per transaction "t", in microseconds. The  
30 time that it takes to fill up one memory buffer (B divided

by D) is advantageously greater than the time it takes to read or write two memory buffers (2B divided by S) plus the average seek time (t):

5      
$$\left(\frac{B}{D}\right) \geq \left(\frac{2B}{S}\right) + \left(\frac{t}{1000}\right)$$

Solving for the minimum buffer size in the above equation yields the following equation which gives the minimum buffer size:

10      
$$B \geq ((DS)/(S-2D))/(t/1000)$$

A viewer can pause a season premier of a television while the station is still broadcasting in order to get up and answer the telephone. The user can resume watching the show after interruption as if the program were on video tape. In addition, while watching a sports event the user can rewind back to a controversial pass, replay the play in slow motion, stop at the exact instance when the catch was made and zoom in on the receiver. Also, the user can apply an image sharpening filter to see if both of the receiver's feet touched the ground before the receiver went out of bounds.

Timeshifting by simultaneously recording and playing back a data stream enables the following type of benefits/features for an end-user. While watching the season premiere of a television show, the viewer can literally pause the program in order to get up and answer the phone or get a snack from the refrigerator. After the

interruption, the viewer can resume watching again without having missed anything. If the viewer came home 15 minutes late for the show but had started recording the program from the beginning, the viewer can begin watching right away instead of waiting for the show to be over and then rewinding the cassette tape. Also the viewer can replay scenes during a live broadcast (e.g. season premiere of a show or sporting event) in case the viewer missed a line or an exciting play. In addition, while watching a sports event the user can rewind back to a controversial play, replay the play in slow motion, and stop at the exact instance when the catch was made. To get a better view, the viewer can zoom in on a portion of the screen and apply image sharpening filters to magnify one part of the screen.

Thus, a method of simultaneously recording and playing back a time-shifted video stream is disclosed. The specific arrangements and methods described herein are merely illustrative of the principles of this invention. For example, the same method may be used to store and retrieve other types of data streams besides video streams. Numerous modifications in form and detail may be made without departing from the scope of the described invention. Although this invention has been shown in relation to a particular embodiment, it should not be considered so limited. Rather, the described invention is limited only by the scope of the appended claims.

What is claimed is: